FixO3

FIXED-POINT OPEN OCEAN OBSERVATORIES

The Fixed point Open Ocean Observatory network (FixO3) seeks to integrate European open ocean fixed point observatories and to improve access to these key installations for the broader community.

Final Report

Project Months 1-48

Find out more **Web:** www.fixO3.eu **Twitter:** @fixO3Project

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PROJECT FINAL REPORT

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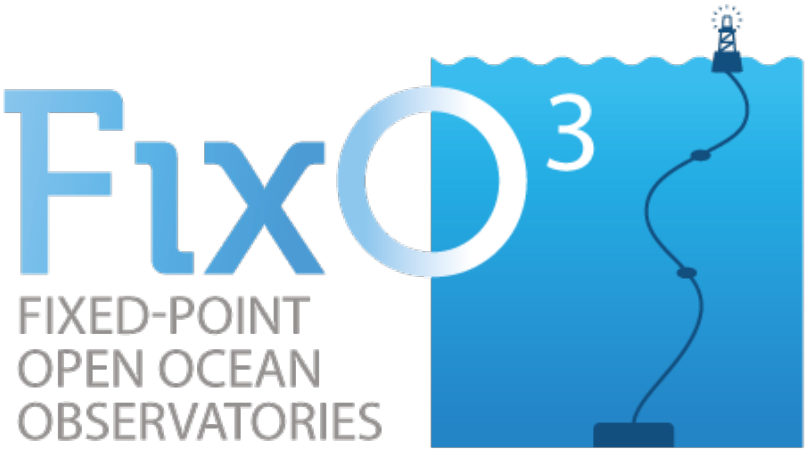

Final Report

Project months 1-48

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FixO3 Final Report

Summary Report

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1. Executive Summary

The global ocean is our planet's largest feature. It influences the life of all of us in a wide variety of ways including supplying food, providing renewable energy and regulating the Earth's climate. Its effect reaches far beyond the continents' coasts where the majority of the world population lives. For centuries its huge extent has led us to believe that we can have no significant impact on its ecosystems.

Yet we know so little about the ocean. Human exploration of the ocean has been limited by several challenges and the study of its features addressed with a variety of means, from satellite remote sensing, to explorative cruises, to the use of remote-operated vehicles, to numerical modelling of ocean physics and biogeochemistry, to permanent fixed observing platforms. Each of these means presents limitations and advantages and contributes in its own way to putting together the pieces of the puzzle that compose the big picture of how the ocean works and changes.

The complexity and extent of the ocean system require studying it as a collaborative effort to overcome the scientific, technical, logistical and financial challenges that one single research institution or government would not be able to tackle alone. Ocean observations, as a mean to understand the ocean system and its changes, are undertaken through collaborative projects and international frameworks, such as the Global Ocean Observing System (GOOS, http://www.ioc-goos.org/), the global system for sustained observations of the ocean comprising the oceanographic component of the Global Earth Observing System of Systems (GEOSS).

The Fixed point Open Ocean Observatory network (FixO3) was developed to integrate European open ocean fixed point observatories and to improve access to these key installations for the broader community. These provided multidisciplinary observations in all parts of the oceans from the air-sea interface to the deep seafloor. Coordinated by the National Oceanography Centre, UK, FixO3 build upon the significant advances achieved through the FP7 programmes EuroSITES, ESONET and CARBOOCEAN. With a budget of 7 Million Euros over 4 years (started in September 2013) the project had 29 partners drawn from academia, research institutions and SME's. In addition 14 international experts from a wide range of disciplines comprise an external Advisory Board.

The programme was achieved through:

1. **Coordination activities** which integrated and harmonised the current procedures and processes. Strong links were fostered with the wider community across academia, industry, policy and the general public through outreach, knowledge exchange and training.
2. **Support actions** to offered a) access to observatory infrastructures to those who do not have such access, and b) free and open data services and products.
3. **Joint research activities** which innovated and enhanced the current capability for multidisciplinary in situ ocean observation.

Open ocean observation is currently a high priority for European marine and maritime activities. FixO3 provided important data on environmental products and services to address the Marine Strategy Framework Directive and in support of the EU Integrated Maritime Policy. The FixO3 network provided free and open access to in situ fixed-point data of the highest quality, a strong integrated framework of open ocean facilities in the Atlantic, from the Arctic to the Antarctic and throughout the Mediterranean, enabling an integrated, regional and multidisciplinary approach to understand natural and anthropogenic change in the ocean.

2. Description of project context and the main objectives

With 71% of our planet covered by the oceans, they exert a massive effect on all aspects of human life and the global climate. In order to understand the role of the oceans and the consequences of the changes currently taking place, sustained time-series observations are required of a variety of key properties from the surface to the deep sea floor. Climate change is being experienced most acutely in the Arctic and there is a strong case for enhancing our focus on this particular environment, challenging as this may be. These observations are made by a variety of autonomous platforms (floats, gliders, ships, moorings, benthic landers and satellites) and from sample collections all of which methods have advantages and disadvantages. Ultimately, these observations must be assimilated into appropriate computational models but before that goal can be achieved, the observing infrastructures must be integrated into coherent and complementary networks. The fixed-point open ocean observatories currently operated by European organisations cover a wide range of environments from the lower atmosphere to the sea surface to the base of the upper mixed layer (e.g.100m) throughout the water column and to the deep sea floor. The benefit of integrating these with enhanced access to a broad range of users are logistical, political, presentational, economic and scientific. The vision of FixO3 was to provide that integration which is so essential if full advantage is to be taken of the substantial investments currently being made.

Coordination Activities

To avoid fragmentation of effort and to enhance the structure and function of the European Research Area, a highly coordinated approach was pursued by the FixO3 consortium with close links between infrastructure operators, users and public authorities. To achieve this, the FixO3 project dedicated a number of work packages to Networking Activities. All work packages are strongly interlinked and address the following topics:

- Technological and procedural harmonisation (WPs 2&3)
- Data management and harmonisation (WP4)
- Innovation through industry (WP5)
- Interface with policy and intergovernmental bodies (WP6)
- International and European networking of fixed-point observatories (WP7)
- Outreach and training (WP8)

TECHNOLOGICAL AND PROCEDURAL HARMONISATION:

In order to facilitate cross-disciplinary fertilisation within the science community and to fully integrate each observatory infrastructure into a European network, a definition of common standards is critical. Therefore, FixO3 emphasised technological (WP2) and procedural (WP3) harmonisation by formulating standards of acceptability for scientific equipment and sets of instruments, as well as common protocols for operational procedures, and guidelines of 'best practices', all of which were combined to define the FixO3 label. The latter was promoted in compliance with other normative efforts, such as SeaDataNet, MyOcean, and EMODNet, to promote and implement sets of common standards and guidelines for offshore platforms.

DATA HARMONISATION:

Data management and harmonisation (WP4) established standardisation, interoperability and compliance with international and existing European initiatives, such as SeaDataNet, MyOcean, OceanSITES, EMODNet, and PANGAEA. Each infrastructure delivered real-time and delayed-mode data to the Data Assembly Centre (DAC). Real-time and delayed mode data streams were then processed efficiently to produce metadata and data in standardised format. A common FixO3 data policy has been approved and adopted by the Consortium. FixO3 standards and services registry and metadata catalogue were also implemented and integrated into the FixO3

website enabling public access to standards and interfaces used within FixO3 as well as to archived data from each observatory. FixO3 data are available on the FixO3 website as well as the European Marine Ecosystem Observatory (EMECO) site.

INNOVATION THROUGH INDUSTRY:

FixO3 identified contacts within the marine science and ocean observation community for use by FixO3 partners, product, services and data providers assisting key players to connect with innovative researchers, end users and service companies in the marine science market. The commercial sector needs and market size for ocean observatory products and services was defined and a number of companies were selected as members of a FixO3 Technology Cluster. The identification of 5 innovative products from within the observatory community promoted ocean observatory products and services to the commercial sector. WP5 thereby supported world-class research that set out to drive innovation, which increases Europe's competitiveness in the global market, upholds sustainability, and facilitates social progress.

INTERFACE WITH POLICY AND INTERGOVENRMENTAL BODIES:

The role of FixO3 and FixO3-related observational activities in the changing landscape of national, regional, European and global initiatives and systems for ocean observations has been emphasised. Close links with European entities, and programs and alliances, including EuroGOOS, European Marine Board, ESFRI and European Commission activities, have been strengthened.

INTERNATIONAL AND EUROPEAN NETWORKING OF FIXED-POINT OBSERVATORIES:

In order to further consolidate and promote the synergy between European research communities, it is essential to actively enhance international and national collaborations with related projects and networks (WP7). Building upon the integrating process of ESONET-NoE, ESONET-Vi (ESONET – the vision) represented the main link between relevant projects such as EuroSITES, EMSO-PP, CARBOOCEAN, Euro-Argo, Eurofleets, JERICO and FixO3. The aim was to augment and enhance collaborations with international (e.g. OOI, Neptune Canada, DONET) and European Eulerian observing systems that are not part of the consortium, to extend integration beyond FixO3. In addition, it is essential to ensure long-term stewardship of the FixO3 network in order to provide coherent time-series data. Therefore, FixO3 developed strong links to international and European organisations and conventions, including GEO and GEOSS, GMES and EuroGOOS, the IPCC, UNEP, OSPAR, EMSO ERIC, as well as the Marine Strategy Framework Directive (WP6). It thereby increases European competitiveness and transforms the ability of science to inform government policy and business strategy with greater certainty and efficiency than has so far been achieved.

OUTREACH AND TRAINING:

The dissemination of information to the consortium as well as to the public and government organisations was carried out by WP8 on outreach and training. The FixO3 website developed targeted presentations of project outputs and "knowledge" to scientists, policy makers, industry and the general public by producing a series of high-impact visualisations. To promote best practices, WP8 also organised and implemented training for less experienced users of hardware, data, and data products. The FixO3 consortium was coordinated by WP1, which included the management of the project and interactions with the Project Steering Committee and the Advisory Board.

Support Actions

The FixO3 network offered two main types of SUPP activities: 1) Access to 15 sustained open ocean observatory infrastructures (TNA). A shallow-water test site for testing instrumentation and technologies whenever needed during the course of the project (WP9); 2) Access to fully multidisciplinary online data services and products (SA) on the entire oceanic environment, from seafloor to the air-sea interface, including a focus on carbon fluxes (WP10).

TRANSNATIONAL ACCESS TO FIXO3 INFRASTRUCTURES (TNA):

The FixO3 sustained open ocean observatories offered under trans-national access cover a broad geographical range from the Polar Regions (Arctic and Antarctic) to the Atlantic and Mediterranean. Each of the infrastructures chosen for transnational access are in key regions identified by EMSO as critical areas for environmental monitoring. Furthermore, many of them link to planned ESFRI infrastructures such as EMSO, ICOS and SIOS. The objective of WP9 was to support external scientific users by providing coordinated, free-of-charge, transnational access to state of the art fixed open-ocean observatories.

SERVICE ACTIVITIES (SA):

The FixO3 Service Activities detailed in WP10 include high impact data services and products from 23 fixed-point multidisciplinary open ocean observatories. These are ready-to-use data products for multidisciplinary use and for derived information including time series ecosystem variables. The integrated data services offering regional scale visualisation of datasets and products from open ocean observatories have been selected according to their relevance to central GEOSS themes as well as their compliance with SeaDataNet standards and the GMES initiative. The service activities build on the current fixed-point open ocean data services and the progress made in previous EU projects EuroSITES, HYPOX, ESONET and CARBOOCEAN which integrated and enhanced European observatory data streams.

WP10 provided access to the data products and knowledge derived from most of the FixO3 observatories. The FixO3 Services were presented in four main themes for data provision in sccordance to GEOSS tasks:

- Ocean and Climate
- Carbon fluxes and Ocean acidification
- Ecosystem function and Biodiversity
- Geodaynamics and Geohazards

Joint Research Activities

OPTIMISATION OF OCEAN OBSERVING CAPABILITY:

The first of these JRA endeavours (WP11) was to develop the ways in which the fixed-point infrastructures of FixO3 best interact with other observing systems. This WP produced a roadmap towards an optimum and integrated observational network of FixO3 platforms, complemented by all other platforms, identifying a vision to the future planning and improvement. This was based on the following activities:

- Research the structure of a minimum and an optimum Virtual Observing Network (VON) to fully describe the carbon fluxes and related biogeochemical cycles.
- Qualitatively evaluate the current network of FixO3 platforms and the parameters measured against those of the VONs
- 3Qualitatively research the capacity of platform cross-calibrations to improve the observational network

Besides the final publication of recommendations, the developed numerical techniques were made publically available, aiding the re-evaluation of an observational network as scientific and technological advances are incorporated in such a network.

RESEARCH AND DEVELOPMENT ON CRITICAL OBSERVATORY FUNCTIONS:

The second JRA endeavour (WP12) focused on the current infrastructure hardware communication systems and the ways to interpret the data obtained. The objective was to enhance the capability of the infrastructure to make very high quality observations, to communicate the data reliably and to convert it into environmentally relevant variables on appropriate timescales. An additional task researched the development of new platform design.

Project Legacy Preparations

EMSO ERIC

The European Multidisciplinary Seafloor and water column Observatory (EMSO) is a large scale, distributed marine Research Infrastructure (RI) of fixed-point observatories serving marine science researchers, marine technology engineers, policy makers, and the general public across a wide range of scientific disciplines and industry sectors

EMSO, a new ESFRI European Research Infrastructure Consortium (ERIC) with eight founding Member States, contributes to a variety of European and international endeavours and ultimately will become the pivotal voice of European fixed-point ocean observation in the Global Ocean Observing System (GOOS).

FIXO3 MODULES TO MIGRATE TO EMSO

The overarching objectives of FixO3 were to integrate European ocean fixed-point observatories, improve access to key installation and to data, and to provide multidisciplinary observations in all parts of the ocean vertical profile, from the air-sea interface to the deep seafloor. There is potential for this legacy to be exploited by EMSO to avoid duplication and to build on what has been achieved within FixO3. In contrast to situations in the past when legacies of EU projects have sometimes been forgotten, FixO3 aims to migrate key project outputs to long-term infrastructures, (i.e. EMSO-ERIC), as part of the project's legacy. To facilitate the migration, these outputs have been organised in thematic 'modules' and it was identified early on that each of them would require time and effort to transfer and rebrand them for EMSO. Furthermore, resources will be required in the future to ensure that each module remains current and relevant as time passes and conditions change.

Modules proposed to be transferred to EMSO ERIC:

- **Module 1** – Handbook of Best Practice
- **Module 2** – Metadata Catalogue, SWE & web access to data
- **Module 3** – FixO3 Label
- **Module 4** – Description of Observatories; Handbook of Instrumentation; and Yellow Pages
- **Module 5** – Outreach and Training Materials
- Recommendations for **Links to Industry**

3. Description of the main S & T results/foregrounds

The results of the FixO3 project are outlined in the deliverables and milestones and have demonstrated an increase in data delivery, an escalation in our interaction with the commercial sector (SMEs), developments of new technology to enhance observing capability and a deeper understanding of how fixed point observing systems should function. In addition, through two TNA calls, there was a significant level of collaboration research groups throughout Europe who have hitherto not been involved in this type of activity.

This section highlights the significant achievements made throughout the project timeline, 1 September 2013 – 31 August 2017.

WP2 – TECHNOLOGICAL HARMONISATION

The main objective of this work package was to build on the progress made by preceding programmes and to review the current status of existing operational systems used in Europe and to define the best technical practices for compatible, robust and cost-effective systems on a variety of fixed platforms.

Main Achievements:

- **Assessment** of existing and novel hardware (Task 2.3)

- **The "Handbook" on relevant info about sensors and devices** providing information on the operating systems, through an overview of the applications of the most common sensors, as well as including practical instructions for the 'user'.

- **Eased and harmonised standard sensor description.** A pilot editor tool has been developed to facilitate the creation of sensor and sensor platform descriptions

- **Development and further connectivity and capability of open access database dedicated to deep-sea and ocean services: *Open Ocean Observatories Yellow Pages* (O3YP)**. Originally created in the framework of the ESONET Project and respectively named *ESONETYellowPages*, was further developed under FixO^3 and renamed. The yellow pages aim to organise information concerning 'Off the Shelf' products for the development and maintenance of Vdeep-sea Observatories. O3YP now offers: Open access catalogue of sensors, hardware and services related with ocean observatories; Is freely available on line; All users can search for specific sensors; Authenticated users can add sensors, services or hardware;

WP3 – PROCEDURAL HARMONISATION

Main Achievements:

- **Assessment** of operational procedures for sustained Eulerian observations

- **Handbook of Best Practices published**. Under the first authorship of Laurent Coppola (CNRS), several FixO3 experts spent a large amount of time producing a document that describes the principles and practice of the best way to make time series Eulerian observations covering all aspects from the preparation and calibration of sensors, handing of samples and maintenance of moorings. As technology and the rational for Eulerian observatories evolve, this document will need repeated updates but the intention is that it will remain as a single item reflecting the currently perceived Best Practice.

- **The FixO3 label for offshore platforms** including requirements of variables measured, the frequency of measurement, and quality control of data as well as assured sustainability is defined.

WP4 – DATA MANAGEMENT AND HARMONISATION

Main Achievements:

- **Streamlined Data Policy**. Development of a brief (2 page) policy providing a formal base for data exchange by defining specific data formats and transport protocols that observatory operators agreed to adhere to by signing a Statement of Compliance for the FixO3 data policy. This policy has also come to the attention of the European Marine Observing community.

- **Metadata Catalogue & Standards and Services Registry.**The FixO3 Metadata Catalogue offers a simple and advanced search modes and returns matching results from within the FixO3 data holdings. Development of a web based registry of FixO3 standards and services which were maintained throughout the FixO3 project and compliant with GEOSS CSR API

- **Sensor Observation Service (SOS) servers and Sensor Web Enablement (SWE) components.** WP4 co-initiated and actively contributes to the marine-swe profiles group* hosted by 52°North. This group develops standardised SensorML and Observations & Measurements profiles for marine observations. These profiles are crucial for flawless communication between SOS servers and clients. The group has grown rapidly, and has members from across Europe and beyond which shows the large interest and the necessity to further develop and propagate these techniques.

- **Monitoring of Service Activities.** Although SA is defined and demonstrated under WP10, management, monitoring and dissemination of SA activities conducted fell under WP4 who ensured excellent quality of the services and maximised public awareness and the use of these services.

WP5 – INNOVATION THROUGH INDUSTRY

Main Achievements:

- **Stakeholder consultation.** WP5 engaged with marine and maritime sector companies to match their needs with equipment, sensors and software being used on FixO3 observatories. SLR Consulting (WP5 Lead) promoted the FixO3 infrastructure and activities to a new group of companies in a range of different sectors including subsea cameras, geophysical and environmental survey companies, project management companies specialised in capacity building for marine companies in the developing world, equipment manufacturers, and integrators of sensors systems.

- **An Industry/Ocean Observatory Forum has been established** to promote interaction between the ocean observatory research community and the commercial sector. WP5 dentified the market for ocean observation products and services. Established a cluster of commercial sector companies who will collaborate with the research community to bid for public and private sector contracts in the Environmental Monitoring sector. The development of such clusters stimulates and enables innovation.

- **Promotion of 5 identified products.** WP5 identified five innovative products and services operating on FixO3 infrastructure with the intention of promoting them to the commercial sector. The selected products and services are based on background intellectual property rights (IPR) held by FixO3 partners before the project commenced, and also products and services from the wider ocean observatory community. These products include:
    - pCO2 optode with Xylem Aanderaa
    - pH with SensorLab
    - COSTOF2 licensed by Ifremer to RTSYS
    - TEXCEL (partner of FixO3) is provider in the EGIM of the interface between COSTOF2 and cable (DPI)

WP6 – INTERFACE WITH POLICY AND INTERGOVERNMENTAL BODIES

During the project timeline there has also been increasing attention to the global level with European involvement in global processes of importance. These include the UN Ocean Conference in New York in June 2017 and voluntary commitments made there, work with the IPCC Special Report on Oceans and Cryosphere, preparations for the OurOcean conference in Malta in October 2017 and later conferences including white papers for the OceanObs2019. The Global Ocean Science Report, released by the Intergovernmental Oceanographic Commission (IOC) on World Ocean Day 8 June 2017, and the major initiative for an International (UN) Decade of Ocean Science for Sustainable Development 2021-2030 form global marine science policy frameworks for the future where European fixed point observatories have new arenas and opportunities for further strengthening.

Main Achievements:

- **Visibility and further implementation and long-term stewardship of deep-ocean fixed-point time series observations.** FixO3 time series accepted as contributing to GISC and EuroGOOS. Integration of FixO3 as a data network into the EMODnet Physics Portal. Five thematic modules will be migrated from FixO3 and implemented into the EMSO-ERIC

- **Interface with policy and intergovernmental bodies**. WP6 ensured recognition by the European Marine Board of the role of FixO3 time series in European and marine and maritime policy.

- **Cost-benefits analysis report**. A paper was prepared by coordination with key contributors on the unique benefits of Eulerian observatories, the cost of a typical infrastructure and the value of data and services produced by FixO3. It was published in Marine Policy journal, Volume 71, September 2016, pages 138-146.

WP7 – INTERNATIONAL AND EUROPEAN NETWORKING OF FIXED-POINT OBSERVATORIES

Main Achievements:

- **Consolidated and promoted the synergy between European research communities**. Through WP7, FixO3 actively enhanced international and national collaborations with related projects and networks (WP7). Building upon the integrating process of ESONET-NoE, ESONET-Vi (ESONET – the vision) created the link between relevant projects such as EuroSITES, EMSO-PP, CARBOOCEAN, Euro-Argo, Eurofleets, JERICO and FixO3. Furthermore, an agreement was put in place to transmit relative ESONET Vi components to EMSO and ICOS ERICs via EMSO-Link project

- **Link ocean scientists and engineers into an international team in marine science**. During the project timeline, WP7 organised conferences bringing together international experts in ocean observations and marine sciences. In November 2016 a 4-day conference was held on “Time series analysis in environmental science and application to climate change”, in Tromsø (Norway), gathering a total of 67 participants, speakers and lecturers, during two days of training followed by two days of plenary sessions.

- **Successful management of TNA activities.** Although TNA activities were demonstrated through WP9, the preparation, evaluation and management of Transnational activities sat within WP7. There were two TNA calls launched during FixO3, where WP7 designed the calls, defined the evaluation and selection criteria for applications of TNA access, preparation of reports and management of funds for T&S support available to end users.

WP8 – OUTREACH AND TRAINING

The dissemination of information to the consortium as well as to the public and government organisations was carried out by WP8 who were tasked with the presentation of project outputs and knowledge to scientist, policy makers, industry and the general public through the project website, social media and high impact visual outputs. Furthermore, through WP8 FixO3 conducted several capacity-training workshops, whose materials were collated and made readily available on the website. Lastly, WP8 also developed and implemented visual dat products and developed a visualisation tool to ensure data and information products resulting from Service Activities and Joint Research Activities were easily and readily available to end users.

Main achievements:

- The **FixO3 website** has been a very successful communications tool throughout the project and also provided a platform for access to information on the observatories, Trans-National Access, Service Services Activities, observatory data and data visualisations. The number of visitors to the website has been significant throughout the project and there have been over 250k visualisations of data products.

- **High Impact, fully integrated set of data visualisations**. EarthVO (Earth Virtual Observatory) is a platform independent data visualisation tool that allows users to analyse integrated data in a flexible and rapid way. For the FixO3 project, individual plots have been embedded into the observatory pages and an application has been implemented into the FixO3 website

- **High Impact Visual Outputs related to FixO3 and ocean observatories. Visual outputs prepared during FixO3 include:**
    - General FixO3 poster
    - A brochure on the observatories offered under TNA
    - A poster and accompanying fact sheet on the achievements of FixO3
    - A videography on ocean observatories and their importance – available on YouTube
    - A Wikipedia entry
    - 4 Annual project newsletters

- **Capacity Training Workshops:**
    - **Workshop for less experienced users of data** (15-16 April 2015, Bremen, Germany) "An introduction and practical use of European marine data infrastructures". A 2-day workshop, hosted by PANGAEA and Marum, on the uses of existing data infrastructures, importance of metadata, property rights, and uses of key online and stand-alone software and tool. The workshop attracted 19 attendees and guest speakers from EMODnet/EuroGOOS, MyOcean, ICES, EurOBIS, PANGAEA and SeaDataNet

    - **Course – A Practical introduction to marine monitoring hardware and procedures**, (15-17 September 2015, Trieste, Italy) A hands-on 3-day practical workshop involving exposure to some of the latest precision ocean monitoring sensors and equipment at OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale) in Trieste, Italy. The aim of the workshop was to provide an opportunity for early career scientists to develop a working knowledge of the challenges of ocean monitoring and to work with the equipment, calibration and operational procedures for the measurement of some key parameters including temperature, salinity, O2, pH and pCO2.

    - **Course – A Practical introduction to acquisition, validation, quality control and access to (biodiversity) data,** (14-15 June 2016, Yerseke, The Netherlands) NIOZ organised a 2-day course for less experienced users of data on acquisition, validation, quality control and access to biodiversity data. The aim of this course was to introduce less experienced users to methods and techniques for processing biodiversity data, integrating physico-chemical and biodiversity data, and delivering data products that may be required to meet policy needs such as GES descriptors.

WP9 – TRANSNATIONAL ACCESS TO FixO3 INFRASTRUCTURES

The FixO3 project's 'Transnational Access (TNA)' initiative is about supporting, financially and logistically, external scientific users and includes 14 ocean observatories in the open ocean and one shallow water test site in the Western Mediterranean Sea available for access by successful applicants. Observatory locations range from the polar regions of the Antarctic and Arctic, to the Atlantic Ocean and Mediterranean Sea with a choice of seafloor, id-water and surface infrastructures with varying scientific focus due to each location's characteristics. These observatories were selected as they offer the broadest scientific and technological capabilities for multidisciplinary observations such as atmosphere-ocean interactions at the sea surface and processes in the water column and ocean floor. Gliders are also available for some of the sites. The observatories address a wide range of disciplines such as biology, biogeochemistry, chemistry, physics and geology. There were a total of 22 successfully deployed TNA projects during the FixO3 project timeline. Details of all the projects are included in the Third Periodic Report for each infrastructure that provided access.

WP10 – SERVICE ACTIVITIES

Within FixO3 Service Activities (SA) were developed in order to provide easy access to fully processed multidisciplinary data, services and products. SAs provide scientific knowledge derived from most of the observatories that comprise the FixO3 network. These sustained open ocean observatories cover a broad geographical range from the Polar Regions to the Atlantic and the Mediterranean. The FixO3 SA web pages give end users the opportunity to directly access data-sets, derived data and data products from a central access point. They can be selected either by selecting the overall scientific themes defined by GEOSS or via choosing one of the particular FixO3 observatories directly. http://www.fixo3.eu/service-activities/

WP11 – OPTIMISATION OF OCEAN OBSERVING CAPABILITY

In order to improve our observational capacity, we have to work towards the integration of measurements across platforms. The research done in FixO3 in WP11, together with WP2 and WP12, aimed at the evaluation and design of an optimum observational network for marine carbon cycle science. FixO3 concentrated on measurements of the fugacity of sea surface CO2 (fCO2), performing a number of different statistical techniques to identify the optimum observational network to create spatially and temporarily significant ocean maps, with identified uncertainties.

In areas of high observational density, such as the northern hemisphere (North Pacific and North Atlantic, excluding the Arctic), we performed a number of different Observing System Sampling Experiments, working toward identifying an optimum observational network. Preliminary uncertainty estimations show that the CO2 exchange between the ocean and atmosphere can be done with an uncertainty of approximately 15 %, based on the current surface ocean CO2 observational network of SOCAT version 4.

A manuscript of the research done in FixO3 is in preparation for publication in a scientific journal.

WP12 – RESEARCH AND DEVELOPMENT ON CRITICAL OBSERVATORY FUNCTIONS

The WP12 is the technological R&D work package of FixO3, it succeeded in the objectives of its four tasks to enhance the capability of the FixO3 infrastructures to make very high quality observations (Tasks 1-3) and to develop new low energy consuming platform design in order to promote more sensors per platform and extension of capacities (Task 4).

Main Achievements:

- **Enhancements of CO2 measurements, measurement of marine sound and pH sensors** Success of these tasks have helped to enhance the capability of the fixed-point infrastructures to make high quality observations.

- **An exceptional inter-comparison exercise** was held at the beginning of the project at Koljofjord testing site. The outcome was a list of difficulties that must be addressed to reach an objective of unattended deployment for fixed-point stations monitoring purposes (calibration, biofouling, energy...); it was also convincing enough to foster the two demanding objectives of long-term deployment and deep water measurement.

- **Development of non-cabled platforms for high data volume sensors**, with precise time reference
  - Design of Mooring node EMSO EGIM on cabled and non-cabled platforms (TRL4)
  - Interface design of Seismology node (TRL5)
  - Buoy and 2 benthic nodes adapted to EMSO Azores (TRL7-8)
  - Ready for EMSO – EPOS cooperation on seismic benthic stations (ENVRI+ topic)

4. Potential impact and main dissemination activities and exploitation results

IMPACT

Over the last century, changes in the global climate, the worldwide degradation of ecosystems, rapid population growth and the depletion of resources have led governments and international organisations to acknowledge an urgent need to better understand the causes and consequences of these changes and the rate at which they are progressing.

The overarching impact of this programme will be to establish an integrated network of open-ocean fixed point observatories supported by a dedicated community of experienced scientists and engineers. Nothing comparable exists elsewhere in the world and the impacts of this programme will be felt in terms of research capability, interactions with the industrial community, development of European monitoring capability and in terms of implementation of environmental legislative processes. The impact will be strongly felt in terms of integration of the ERA and in terms of interactions between the community involved in fixed point observations and those involved with other observing initiatives.

Impact for the research community

Consecutive EU Framework programmes have invested significantly in the integration of most scientific fields in order to reduce fragmentation and increase the effectiveness of research investments. However, in spite of this fact and the critical importance of ocean observation for the European Research Area (ERA) fragmentation still exists.

FixO3 has made a substantial contribution to the ERA by developing synergies and complementary capabilities offering improved access to researchers and developing their innovation potential. By providing measurements that integrate the surface of the oceans with the water column, the deep-sea benthos and the sub-seafloor over a range of scales, the FixO3 network has produced critical data for evaluating the potential impacts of climate change and geohazards, as well as information for maritime industries, as supported by the EC Strategy for Marine and Maritime Research. The establishment of procedural standards complemented harmonisation of hardware and software by creating common protocols and guidelines of ‘best practices’ to define a FixO3

label, a guide of recommendations for the use and operation of European open-ocean observatories. The newly established EMSO ERIC will uptake the FixO3 label, which will be rebranded, updated and implemented a the EMSO Label.

Industrial impact of FixO3

To date, the industrial community and those responsible for observatories have had a somewhat remote relationship. Typically interactions occur at trade fairs where products which are frequently not market-ready are sold to the scientific and technical community who unwittingly trial them. From the other perspective the scientific community often fail to communicate their aspirations and ideas effectively to the industrial community largely comprising SMEs leading to lost opportunities for innovation and manufacturing. FixO3 has improved this by providing mutual support and stimulation so that capability to observe the oceans and the opportunity for increased industrial development and worldwide sales.

An Industry/Ocean Observatory Forum has been established to promote interaction between the ocean observatory research community and the commercial sector. This promotion, in the form of an "Innovation Meets Industry" workshop, is now an integral part of the trade exhibitions Oceanology International and Ocean Business. Five products and services were identified and a suite of IPR agreements established to aid commercialisation negotiations. The platform will persist beyond the ending of the FixO3 project and the individual companies in the Industry/Ocean Observatory Forum will continue to organise the annual event at Oceanology International and Ocean Business.

Impact on open-ocean monitoring

Over the 4 year project, the FixO3 network has collected data essential for the marine core services developed by GMES (GISC) and GEOSS, which enhance our understanding of temporal trends and improve long-term forecasting. These feed directly into other organisations, including the IPCC, UNEP, ISA, OceanSITES, EuroGOOS and OSPAR to help form and revise policy and legislation. Another crucial aspect of the FixO3 consortium is the strong linkage to related projects, such as JERICO, CarboChange, EuroArgo, Eurofleets, GROOM and Lifewatch, as well as OOI, Neptune Canada, and DONET. Through work packages 3, 6 and 7 FixO3 integrated links with the ESFRI infrastructures EMSO and ICOS and reinforced important relationships with programmes such as SIOS and EPOS.

In contrast to situations in the past when legacies have been largely forgotten, it was identified early on that each of the modules which comprise the FixO^3 legacy would require effort to transfer them to EMSO and to rebrand them and would then require manpower so that they remain as living and relevant entities as time passes and conditions change. One of the most important sessions during the final FixO3 General Assembly (29th June 2017) was to discuss this legacy in plenary and to determine what was actually required if EMSO wished to take advantage of it, what would be the resources and costs for transfer and maintenance in the future. Five modules of FixO3 activity have been proposed for uptake by EMSO, including the Handbook of Best Practice, the Metadata Catalogue, SWE & web access to data, the FixO3 Label, the Description of Observatories; Handbook of Instrumentation; and Yellow Pages, and lastly Outreach and Training Materials compiled during the project.

In addition, ICOS has formed a Marine Thematic Centre to coordinate its marine efforts. Because the EMSO- PP project has been working with a limited number of sites and member states, FixO3 provided critical support for the broader fixed-point open-ocean observatories and related communities such as ESONET-Vi. FixO3 will enhanced networking, knowledge transfer, and access support needed to nurture the continued preparatory activity for operational observatories that were not expected to be part of the EMSO-ERIC. Thus, FixO3 continues to foster the inclusion of successful observatories into networks designed for lasting integration. Indeed, FixO3 represents a critical pathway for observatories that wish to integrate but are not currently ready to enter the EMSO-ERIC.

Data management themes that were advanced by FixO3 include refining metadata standards and implementation of a Sensor Registry developed in ESONET for the broader FixO3 community. These activities benefit EMSO and ICOS, but also have greater applicability to activities of EMODNet and the efficacy of data centres such as PANAGEA and Coriolis. The Service Activities (SAs) of FixO3 add great value to the data collected by its infrastructures. A common theme of SAs is the transformation of raw data into derived data products and other services that address the needs of various user communities and societal needs identified by GEOSS. The evaluation of the SAs by an expert panel ensured that they evolve to best meet community needs.

The scientific areas in which FixO3 was particularly active in are:

Ocean physics and climate change related Service Activities
8 sites (broadest geographical coverage Arctic, Norwegian Sea, Atlantic, Mediterranean): FRAM, CIS, TENATSO, Biscay-AGL, ANTARES, W1-M3A, E2-M3A, Pylos,

Carbon cycle and Ocean Acidification related Service Activities
5 sites (6 SAs; all Atlantic except DYFAMED): PAP, FRAM (x2), Station M, ESTOC, DYFAMED (only 1 Med)

Biodiversity and Ecosystem Assessment related Service Activities
3 sites (3 Atlantic), 1 , 1 integrating: PAP, FRAM, MoMAR, EMECO (trans-observatory)

Sealevel, Geophysics and Geodynamics related Service Activities
3 sites (2 Atlantic, 1 Med): MoMar, ESTOC, NEMO-SN1

Impact on ocean legislation

FixO3 has played an important role in addressing the legislative obligations defined by institutions such as the European Marine Board, Maritime Policy, the EEA, the Water Framework Directive and the Marine Strategy Framework Directive (MSFD). FixO3 has made a significant contribution to the vision of the MSFD which aims to achieve Good Environmental Status (GES) in Europe's seas by 2020. For the MSFD to be implemented, the Commission recognises that "...*an all-embracing maritime policy [...] should be supported by excellence in marine scientific research, technology and innovation*.". The FixO3 network addresses the following Descriptors used for determining GES:

- Descriptor 1: Biological diversity
- Descriptor 4: Elements of marine food webs
- Descriptor 6: Seafloor integrity
- Descriptor 7: Alteration of hydrographical conditions
- Descriptor 11: Introduction of energy, including underwater noise

The project underpins the evaluation of baseline data both related to human impacts, such as underwater noise (Descriptor 11), as well as biodiversity (Descriptor 1) and geohazards (Descriptor 6). The monitoring programme envisioned by the MSFD is tasked to provide assessments of GES using standardised methods to identify causes of change and to understand natural variability. A key driver for most observatory efforts is to help differentiate between natural and anthropogenic perturbations and FixO3 has contributed in a substantial way to the goals of the MSFD.

Impact on integration in the European Research Area

A more coordinated approach between observatory operators, users and public authorities facilitates development and sustainable operation resulting in a structuring impact of the ERA. By establishing a set of common standards and best practices, FixO3 played a key role in integrating technology and procedures across European Seas. An open- access policy for collected data increases access to a much wider European community, particularly in those areas where access to high-quality data is rare. ESONET Vi was actively

supported (WP7) so that as other observatories not included in FixO^3 were able to develop, the operators were able to benefit from the expertise of the FixO3 partners.

Linking into larger frameworks, such as GEOSS, GMES, and EMODNet is another integral part in increasing European competitiveness and transforming the ability of science to inform government policy and business strategy with greater certainty and efficiency than has so far been achieved. The FixO3 consortium has addressed a large number of highly relevant research topics, including climate change and the oceans, marine biodiversity, and geohazards, all of which require a cross- thematic approach. Only an integrated pan-European infrastructure such as the FixO3 network, and moving forward EMSO ERIC, can provide comprehensive and multidisciplinary data sets that are necessary to tackle any of these topics. The establishment and development of such a network will greatly advance the ERA increasing its competitiveness and stature.

Interaction with other initiatives

Due to the diversity of current complementary observing systems, FixO3 was able to have strong and clear interactions with other initiatives to ensure that overlap is minimised and that expertise and knowledge is shared. Table 1 below demonstrates this breadth of activity and the means by which FixO3 will ensure collaboration. Several of the FixO3 partners are also AtlantOS and JERICO partners and a key member of the SSC of both these programmes sit within the FixO3 SSC and Advisory Board.

Table 1: Information flow between FixO3 and European projects and initiatives

Projects/initiatives	Connections with FixO3	FixO3 partners with substantial involvement
AtlantOS	SSC, Advisory Board, WP3 & WP7	NOC, IFREMER, HCMR,
JERICO	SSC, Advisory Board	NOC, IFREMER, HCMR
EuroArgo	SSC, Advisory Board	IFREMER,
MyOcean		IFREMER
SeaDataNet		IFREMER
EuroGOOS	Advisory Board	
ECOOP		
Eurofleets		IFREMER
CarboChange	SSC	
EMSO	SSC	
ESONET	SSC	NOC, INGV, IFREMER
HYPOX		
HERMIONE	**SSC**	NOC
HERMES		NOC
Green Mercator	Advisory Board	
NEPTUNE Canada	Advisory Board	
OOI	Advisory Board	
DONET	Advisory Board	
BP	Advisory Board	UNIABN, NOC
BG-Group	Advisory Board	NOC
Statoil	Advisory Board	UiB
Shell	Advisory Board	NOC
OceanSITES	SSC, Advisory Board	
EEA	Advisory Board	All (through GISC)
ESF Marine Board	SSC	All
CDIAC	Advisory Board	
IOCCP		
MARBEF	SSC	NIOS
GEO		
GEOBON	SSC	
CoML	SSC	

Dissemination of foreground

Open access to data, data products and services

As aforementioned, FixO3 has built on data management principles, policies and standards developed by previous relevant projects such as EuroSITES, ESONET and CARBOOCEAN. The overarching philosophy remains that data should be open access and disseminated as quickly as possible for use by a wide range of target audiences. Open and free access to data was maintained at each level of data distribution with an appropriate delivery time corresponding to the stage of data processing. For instance, raw datasets from autonomous sensors with satellite transmission capability was made available in near real-time (eg within 2 hours). At the other extreme, time series "interventive data" on benthic diversity was not available for 12 months after each sample collection. Visualisation was achieved online through EarthVO (Earth Virtual Observatory) asan independent data visualisation tool which allows users to analyse integrated data in a flexible and rapid way. Quality controlled datasets were made available to download in a timely manner from online portals (e.g. FixO3, OceanSITES Global Data Assembly Centre, EMODNet Physics).

Data dissemination

All collected data and metadata were harmonised with EDMONet, SEADATANET, PANGAEA, EuroSITES (European contribution to JCOMMP OceanSITES program), and MyOcean (the Marine Core Service for GMES) infrastructures. The FixO3 project brought together the fixed-point open ocean and carbon observation communities. As a result, dissemination of the FixO3 data, products and services were targeted to a range of relevant European and International data initiatives. In addition, data were made available not only through the FixO3 portal, but also accessible through ongoing relevant initiatives including the international OceanSITES Data Assembly Centre and online ftp portal coordinated by CORIOLIS (IFREMER; P11), the ICOS Ocean Thematic Centre and the *Carbon Dioxide Information Analysis Center (CDIAC).*

Engaging with the Wider Community

Aligning with the GEOSS implementation plan, FixO3 carried out dissemination and communication activities directed towards key target audiences, including decision-makers and policy makers; industry and service communities; scientific and technical communities; the general public and education entities. Work Package 8 focused on outreach and training, led by the SME Blue Lobster IT which has a track record in outreach, knowledge exchange and data visualisation for National (UK) and European marine science projects. A central part of the FixO3 dissemination plan was the website, with portals and areas specifically developed for disseminating information, data and products from the project, to a wide range of users. Blue Lobster IT hosted and developed the project website, with significant contributions from Coordination partner NERC, which fed into the online data visualisation and interaction with WP4 (Data management and harmonisation).

The primary aims of the FixO3 outreach and knowledge exchange activities were to engage with, educate, and inform public, scientific and industry stakeholders. In addition to the work carried out by WP8, it had strong links to WP6 to ensure any bidirectional communication between the project and policy and intergovernmental bodies, as well as strong links with the transnational access Work Packages WP9 and WP10 (and corresponding management tasks in WP2, 4 and 7). These interlinked and integrated activities ensured that relevant content was provided to the website as the central hub of online information for FixO3 open ocean observatory infrastructure and services. Furthermore, the calls for transnational access are widely publicised through a range of dissemination tools including the website, presentations, visual outputs and communication briefs targeted to policy and decision makers across European member states.

Another aspect of outreach and dissemination in FixO3 were three targeted training workshops (WP8 Tasks 8.6, 8.7, 8.8) to act as a powerful knowledge exchange mechanism between experts within the FixO3 network and users of hardware, data and data products. Workshop information and course content were then collated

and made available thought the website. These materials are also part of the proposed modules to be transferred to EMSO ERIC for further dissemination and/or development of new capacity training opportunities.

Lastly, WP8 also used social media and Citizen Science to communicate and engage with the general public, for instance with cruise diaries during maintenance and research expeditions and for updates on research and innovation activities, workshops and training courses, conferences and industry events.

Exploitation results and IP Management

Partners were encouraged to pursue relevant protections for any inventions suitable for patent, or other forms of protection (e.g. non-disclosure, registered designs, copyright, trademarks). The project put in place a strategy to deal with the full range of IP-related issues in accordance with the Commission's Model Grant Agreement, including Special Clause 29 (Access Rights to Foreground for Policy Purposes and Transfer of Ownership of Foreground). The project Consortium Agreement, detailed the projects IP approach, with particular concentration on issues such as publication, confidentiality, joint ownership of knowledge and pre-existing know-how. The Consortium Agreement also detailed the rights of the Community with regard to access to Foreground Knowledge for the purpose of developing, implementing and monitoring environmental policies. Responsibility for the management of IP issues and the implementation of the terms of the Consortium Agreement rested with the Project Steering Committee.

FixO3 Label developed provides a reference standard to verify if an observatory complies with FixO3 Best Practices by Research Infrastructures EMSO ERIC and others. EMSO ERIC organized through the EMSOLink project will transfer the FixO3 label to become the EMSO label, apply at least until December 2024.

Open Ocean Observatory Yellow Pages (O3YP) provide information on equipment and sensors that can be purchased for fixed-point ocean observation platforms. 03YP were developed from the ESONET Yellow pages during FixO3, were improved by including a reference to metadata constitution in the ocean data management systems and by a reference to observatory using the equipment, and renamed. These too are part of the module migration to be transferred from FixO3 for long term sustainability of their maintenance, updating and dissemination.

Within FixO3, 52°North advanced its Sensor Web components through installation and testing at several infrastructures, resulting in a new SensorML editor (SMLE). An exhaustive user manual was produced in order to foster its use across the community. SMLE is a user-friendly editor that was developed under an open source framework, and available at the following URL: https://github.com/52North/smle ; Its latest deployment for demonstration is available at the following URL: http://pilot.52north.org:3000/#/templates.

Partnerships have been developed with 5 selected companies whose products are of interest to the commercial sector. At Ocean Business 2017, the five companies identified, were approached to give feedback on what barriers to increasing sales to the offshore environmental monitoring sector they have encountered, and potential business solutions to overcome these barriers. Three of the companies were available to give specific feedback on their experiences in FixO3.

Adaptation to NeXOS stand-alone fixed point stations of the Ifremer COSTOF 2 design. The foreground will be the adaptation to FixO3 platforms or to a unified fixed-point front-end technology. It is potentially a product. The design is a background development of Ifremer and still confidential. Access to this background may be granted following the conditions of the Consortium Agreement.

Task 4 in FixO3 Work Package 12 is the largest Technological Research activity in the project. It was decided during the negotiation phase to produce one deliverable (D12.7 Prototype of cable-less platform tested during a cruise. Proposed methodology of fast data deployment) to report (during third reporting period) the various topics of this work. Coming from the experience of previous projects, it focussed on stand-alone observatories for two reasons:

a) they are common technologies between the three communities involved in FixO3 (i.e. EMSO /ESONET, Carbocean and EuroSITES)

b) the other competing technology, cabled observatories, is more powerful but was considered during the evaluation of EMSO by ESFRI national representatives as limited in number of observatories due to the limited Research Infrastructure budget during the coming years.

The electronic development could benefit from previous Ifremer development of a front end device called COSTOF2. It was decided to use the resources and skill of FixO3 partners TEXCEL and IFREMER to adapt on time a link of COSTOF2 with cabled observatory: the OBSEA tests of EMSODEV project demonstrated the good functioning of this device called DPI (Figure WP12.10). An additional result for the COSTOF2 is the industrial transfer of license by IFREMER to a company called RTSYS in the West of France. The support of FixO3 WP5 for a product-oriented view of the project has been fruitful.

5. Project public website

The project public website is available at www.fixo3.eu

The website includes publicly-available information on the project including the description of each observatory, each work package and each participating institution in the FixO3 network. Public deliverables are available for download, as is a Project Information Pack summarising the project's objectives, partners, work packages and observatories. A Standards & Services Registry and a Metadata Catalogue are also publicly available in two sections of the website. Information on TNA access, rules and calls is accessible in a specific section. The website includes also an up-to-date list of news and events concerning the project.

Anyone interested in the project can register to the website and receive the yearly newsletter as well as download the data plots.

Consortium partners are given access to the website's restricted area by the website administrator, Simon Keeble from Blue Lobster IT (admin@bluelobster.co.uk), can access and download all deliverables, edit the information for each observatory and access the media page.

External users can contact project management as well as the website administrator on any issue through a contact form available on the website.

6. List of beneficiaries and principal contacts

Partner Number	Short Name	Full Name	Country	Principal contact
1	NERC	Natural Environment Research Council	United Kingdom	Richard Lampitt r.lampitt@noc.ac.uk
2	OGS	Istituto Nazionale di Oceanografia e Geofisica Sperimentale	Italy	Vanessa Cardin vcardin@ogs.trieste.it
3	HCMR	Hellenic Centre for Marine Research	Greece	George Petihakis gpetihakis@hcmr.gr
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5	UiB	Universitetet I Bergen	Norway	Peter Haugan Peter.Haugan@gfi.uib.no
6	UiT	Universitetet I Tromsoe	Norway	Jurgen Mienert jurgen.mienert@uit.no
7	PLOCAN	Consorcio para el Diseno, Construccion, Equipamento y Exploitacion de la Plataforma Oceanica de las Canarias	Spain	Eric Delory eric.delory@plocan.eu
8	AWI	Alfred-Wegener-Institut Helmholz-Zentrum fuer Polar- und Meeresforschung	Germany	Antje Boetius antje.boetius@awi.de
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10	SLR	SLR Environmental Consulting (Ireland) Limited	Ireland	Nick O'Neill noneill@slrconsulting.com
11	IFREMER	Institut Francais de Recherche pour l'Exploitation de la Mer	France	Jean-François Rolin jrolin@ifremer.fr
12	BLIT	Blue Lobster IT Limited	United Kingdom	Kathryn Keeble kathryn@bluelobster.co.uk
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22	INDP	Instituto Nacional de Desenvolvimento das Pescas	Cape Verde	Carlos Ferreira Santos carlos.d.santos@indp.gov.cv
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27	CNR	Consiglio Nazionale delle Richerche	Italy	Roberto Bozzano roberto.bozzano@cnr.it
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FixO³
FIXED-POINT OPEN OCEAN OBSERVATORIES

FixO³ Objectives

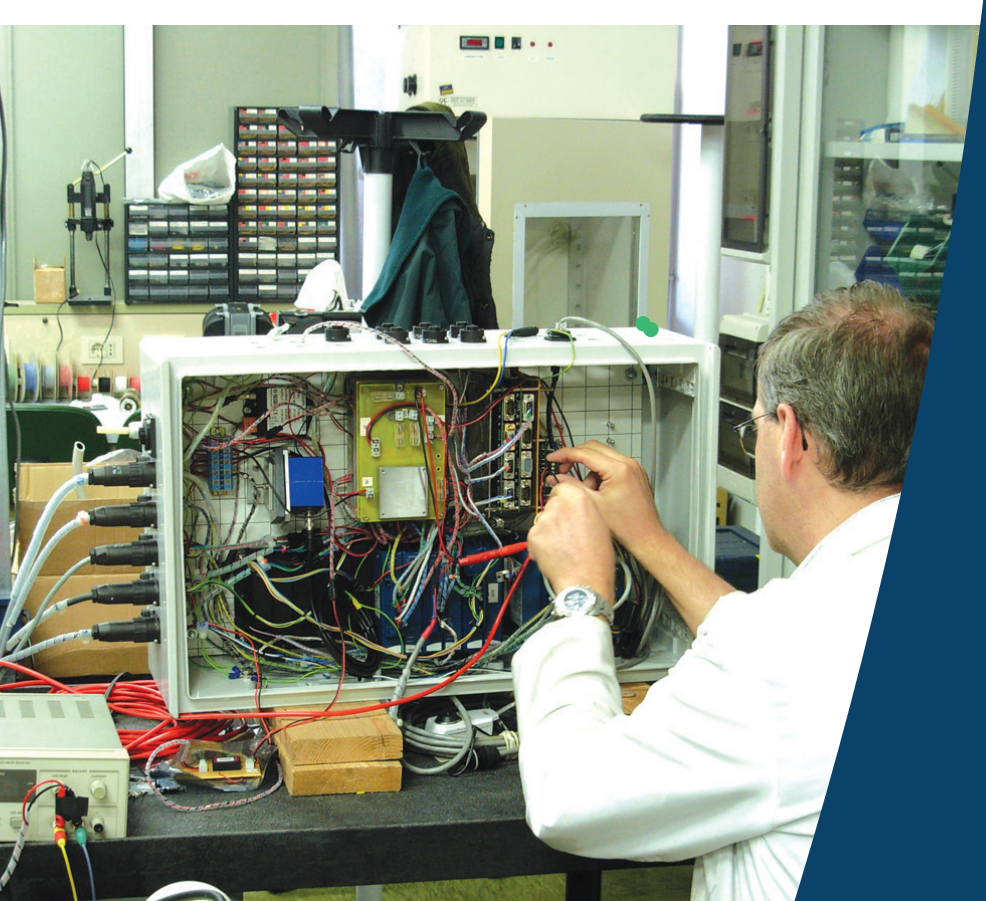
- to **integrate** European open ocean fixed-point observatories
- to **improve** access to these key installations for the broader community
- to **provide** multidisciplinary observations in all parts of the oceans from the air-sea interface to the deep seafloor

FixO³ Activities

Coordination to integrate and harmonise current procedures and processes

Support actions to offer
Access to observatory infrastructures
OPEN data services and products

Joint research activities to enhance the current capability for multidisciplinary in situ ocean observations



29 partners

11 European countries

23 fixed point observatories

12 work packages

4 years

7 million Euros

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